THE VITAL INDEX IN DEVELOPMENT

BY

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University of Oregon

A DISSERTATION SUBMITTED TO THE FACULTY OF CLARK UNIVERSITY, WORCESTER, MASS., IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY, AND ACCEPTED ON THE RECOMMENDATION OF G. STANLEY HALL

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There is perhaps no more important problem for education than that of the physiological development of children during the school age. It would seem that the rate of growth sets a limit to learning beyond which the skill of the teacher can not go. For since the work of Porter (20) there has been good reason to believe that learning is not only conditioned by growth but that in these earlier years the rate of physiological maturing and that of mental development are closely related. Not only this early study but the later work of Smedley (24), Crampton (7), Goddard (13), Arnold (1) and others show that physical and mental retardation go together. The work of Gilbert (12) on the other hand would indicate that the reverse is true. Whether or not these differences in conclusions are due to technique and methods of classification is still a problem. It would seem that there ought to be a close agreement between the grade position of a pupil and the teacher's estimate of his ability, yet the conclusions of investigators using these two methods of classification are not in agreement.

A preliminary investigation of the writer (9) using the grade age method of classification agreed in the main with the conclusions of Porter (20) and Smedley (24). It was noticed in this study that the vital indices of those children below grade averaged much lower than that of those above grade. A study was accordingly begun using the mental age as the basis of classification. It was hoped if a satisfactory method were employed which would select out the mentally

retarded and accelerated that a comparison of the anthropometric measurements of the two groups would reveal some fundamental difference. The two hundred children of the Colorado Teachers' College, one hundred and four boys and ninety-six girls were selected for the study. The number is small but the growth curve of the individual is very similar to that of the group. And the small number enabled one to keep sight of the individual in the group.

The following data were secured, the name, age, physiological age from the teeth, the mental age, grade, height, weight, vital capacity, condition of the teeth and of the tonsils, and the presence or absence of nasal obstruction. To these were added from the records of the school the results of the eye and ear examinations made by Dr. J. D. Heilman of the department of psychology. The height and weight were measured by scales and stadiometer in use in the clinical department. A wet spirometer was used to determine the vital capacity. For this measurement the children were taken in groups and the element of competition introduced into the test. Each child was permitted a number of trials and the best record taken. It may be stated here that the children had had frequent experience with the spirometer. From the above the relation of weight to height was determined, believing that this index would express the general state of nutrition of the individual. The vital indices were also computed. It will be remembered that this index marked the greatest difference between the accelerated and the retarded groups in the preliminary investigation. The classification into the three groups, the accelerated, the normal and the retarded, was based upon the 1911 revision of the Binet scale. The averages are given in the tables.

Historical. In 1889 Gratsianoff (14) in Russia measured the children of Arznus and brought out the fact that the successful children were larger than the unsuccessful and that their rate of growth was quicker. Sack (23) rejected this because of the small number but his own investigation confirmed Gratsianoff's (14) results. These studies were unknown to Dr. W. T. Porter (20) when he began his work in St. Louis, which was undertaken to find the laws of growth, in order that the school work might be fitted to the ability of the pupil. The method of classification was that of the grade age. Porter raised three questions all of which he answered in the affirmative. Are dull children weaker if size is to be taken as the index of strength? Is mediocrity associated with mediocrity of physique? Is there a physical basis of precocity? Bright children were found to be taller and heavier

than dull. Successful children were also found to have larger chests than the unsuccessful. These facts led Porter to conclude that,

"No child whose weight is below the average of its age should be permitted to enter a grade beyond the average of its age except after such a physical examination as shall make it probable that the child's strength shall be equal to the task."

In November of the same year J. Allen Gilbert (12) of Yale published his Researches on the Mental and Physical Development of School Children for the purpose of determining the correlation between the physical and mental development. He classified pupils on a basis of the teacher's estimate as bright, average and dull. He writes in regard to the results:

"The statement is made by Porter that the brighter the child the taller he is. Brightness and dullness in his tests were decided by the examination grades, which it is needless to say are often very poor mental tests. In my results no such relation could be traced."

The same negative conclusion was drawn in regard to weight. The correlation between vital capacity and mental ability was also indifferent and limited. In his Iowa studies of 1897 the same negative conclusions were reached. If anything positive can be stated, Gilbert thinks, it is that the heavier and taller children are the duller.

G. M. West (26) from his study of school children of Canada found as a general rule that the poor, that is the dull children, were more fully developed than the good. In fact the poor were the better developed throughout except girls at fourteen and boys at thirteen. For this reason he considered it safe to conclude that precocity bore an inverse ratio to bodily development.

Smedley (24) reinvestigated the conclusions of Porter using the anthropometric measurements of the school children of Chicago. It is clear from his data that the children who have made the greater intellectual advancement are on the whole taller, heavier and have the greater vital capacity. He found that the pupils of the John Worthy school for truants and incorrigibles were inferior in all the principal measurements taken and that the inferiority increased with age.

Kline (16) found in his study of truants that the mean height, weight and chest circumference was less than the corresponding measurements of public school boys in every instance except the age of ten, when they were equal in height and weight.

Believing that the correlations of Porter were essentially

correct, Goddard (13) compared the growth in height and weight of feeble-minded children with the normal. He found that for boys the feeble-minded were shorter and weighed less, age for age, than the normal. For the girls the situation with regard to height was much the same. For weight the girls seemed to deviate less from the normal than the boys. Having established the above Goddard turned his attention to the difference in the different grades of defect. He concludes that it is evident that the mental condition is correlated with the physical. The idiot he finds to be inferior to the imbecile physically. Size and efficiency go together in the long run. The cause that has acted to impair mind and brain has affected the entire growth process.

As the result of an extended study of physical growth and school progress, based on consecutive measurements at yearly and half yearly periods Baldwin comes to the conclusion that "If pedagogical age be accepted as a fair equivalent to mental development, the tall heavy boys and girls with good lung capacity are older physiologically and are further along in their stages of growth toward mental maturity as evidenced by school progress than are the short, light boys and girls."

On the other hand Wiazemsky (27a) concluded from a study of factors that influence growth that the less endowed surpass the more intelligent in their physical development. This is true especially for the beginning and the end of the period studied by him, that is, from ten to twenty years. The recent study of Arnold on Weight and School Progress brings out again the fact that the heavier children of a given age are to be found in the more advanced grades. His results are confirmed by the results of Hogue, whose tables are reprinted by him.

Historical Summary. Porter and Smedley in the United States conclude that the bright children are taller and heavier than the dull. These results are based on the age grade method of classification. Arnold and Hogue confirm the weight results. Baldwin using school marks comes to the same conclusion. On the other hand Gilbert found no constant relation and West a negative one. Both these investigators used the teachers' estimate of ability as the basis of classification. MacDonald, however, using the same method, confirmed the results of Porter and Smedley. Using spirometry Smedley found that successful children had larger vital capacity than unsuccessful. Gilbert found that correlation to be indifferent or negative, except that from ten to fifteen the dull children have the larger capacities. The investigation of Baldwin and the preliminary study of the writer confirmed Smedley's re-

sults. Wiazemsky measured the chest circumference and found good pupils to be superior at all ages except from twelve to thirteen and from fourteen to fifteen.

Height. Height is the most distinctly human of all the measurements, representing as it does a definite racial characteristic. Heredity preserves a definite norm which all its members tend to attain within rather narrow limits. So having the norm for the different ages established, height gives a fair index of the development of the individual. Bowditch pointed out that the taller individuals, that is, those in advance of the norm for their age reached the rapid growth period earlier. This fact has again been brought out recently by Baldwin. These taller boys and girls he says are the physiologically accelerated boys and girls. They complete their elementary school course earlier, he continues, and as a rule make higher grades than the shorter boys and girls whom he regards as physiologically retarded. If this finding holds as it certainly does for relatively large numbers then height in relation to the norm of a given age is a criterion of physiological age and these taller boys and girls have attained a greater proportion of their mature height. Growth in height is rapid in early childhood and falls to a minimum about ten or eleven. This period of retardation is followed by one of acceleration beginning with pubescence. Acceleration alternating with retardation is a general law of growth, true of the individual as well as of the group. Every study since Quetelet has shown the period of retardation from eight or nine to ten or eleven, followed by a period of acceleration lasting about four years. With girls this period of acceleration begins a year or two earlier than with boys and accounts for the fact that from eleven to fifteen in general, girls are taller than boys. Thus the data presented in this study are typical. But not only are the girls taller during pubescence but also at seven and nine, a fact which may be due to some accident of numbers or may show some variation of growth since the same fact is noted in the results of several investigators. As mentioned before, the pubescent crossing of the curve is due to the earlier rapid growth of the girl. Some investigators think that the comparison should not be one of attainment at a given chronological age but rather should be between the percentages of adult height attained at a given age.

Let us turn now to the analysis of the data on the basis of mental age. The accelerated boys are taller than the normal till twelve. At this age and all succeeding ages studied they are not so tall. On the other hand the retarded are

shorter than the normal at all ages studied except eight and thirteen, when they are also taller than the accelerated. Thus the accelerated are taller than the retarded at all ages except eight and thirteen. If we compare the accelerated and the retarded girls the former are taller until the rapid growth period begins at eleven. At this age they are surpassed by the retarded who remain taller until fourteen. The delayed growth of the retarded girl in the earlier years seems to be compensated for by the three years of rapid growth from eleven to thirteen inclusive. Thus we find retarded boys to be taller at thirteen and girls at eleven, twelve and thirteen. This conclusion is not in accord with Wiazemsky who found good pupils to be superior in height only during the period of rapid growth. The periodicity of growth is much more marked in the retarded than in either the accelerated or the normal. With the latter, growth is much more steady and uniform. With the retarded the earlier years mark a period of very little growth. This is followed by a period of acceleration perhaps shortened in time but compensated for by intensity. Some investigators think that this rapid growth can have only a harmful effect on the individual from the standpoint of the physical and the mental life. As to the cause of the extreme periodicity of growth we can not say. Some investigations indicate that this picture is usually accompanied by effects which follow harmful conditions, namely the precipitate growth and the delay of puberty. (See Table I.)

Weight. Unlike height, which when once gained cannot be lost, weight varies greatly, is easily lost and gained. It is an experimental datum as Montessori (19) calls it, a barometer, an index of the child's health deserving of the most careful study. Environmental factors as illustrated in McKenzie's studies, deprivation, fatigue, anxiety, worry, malnutrition, illness, all affect adversely the weight of the child. A careful study of the weight may not only reveal the effect of factors in the environment but may serve to reveal the strength or weakness of the child's organs.

As with height, growth in weight is not uniform but rhythmic. There is in general a slight acceleration in girls at seven and in boys at eight. The following period of retardation in growth reaches its lowest with girls at nine and with boys at eleven. At about eleven the period of rapid acceleration of weight begins and lasts about four years. In the present study the growth in weight follows the usual course. There is little difference between the sexes until twelve. Girls are slightly superior at seven and nine. The pubertal superiority begins at twelve. As with height this

superiority is due to the fact that the rapid growth period begins earlier with girls than with boys. The accelerated boys weigh less than the normal boys except at the ages seven, twelve and thirteen. Retarded boys are heavier than the normal at eight, twelve and thirteen. When compared with the accelerated the retarded are heavier at the ages of eight and thirteen.

With girls the accelerated are lighter than the normal at all ages except thirteen and fourteen. Retarded girls are lighter than the normal until eleven, then heavier except at thirteen and fourteen. Retarded girls are lighter than the accelerated at eight but heavier in all other groups presented. While retarded boys are lighter than the accelerated at almost all ages, retarded girls are heavier at ten and subsequent ages.

The gain in weight is not so uniform as the gain in height probably for the reasons mentioned in a preceding section. Nevertheless accelerated and normal show a rather uniform rate of growth until the rapid gain at puberty. With the retarded we have the law of compensation at work as in height. The rapid growth of puberty tends to bring both retarded boys and girls above the accelerated at this period, boys at thirteen and girls from eleven on. (See Table II.)

Vital Capacity. The development of the chest is of the greatest importance. No part of the body undergoes greater changes. Hastings speaks of the want of breadth in the infant chest. Woods Hutchinson writes of the widening of the chest in the animal series. The human chest is almost unique, he writes, in that its transverse diameter is the greater. This transformation from the narrow almost animal form to the more human adult form is destined to receive greater consideration in the future than it has in the past. The rate of transformation will give us another index of the rate of the maturing of the individual.

The circumference of the chest has received considerable attention especially in its relation to height. The general rule is that the chest circumference should equal half the total stature. This has been one of the determining marks for military fitness. It is generally conceded that the more the chest circumference exceeds half the height the greater is the vitality and the greater the ease with which the individual adjusts to the varying effects of the environmnt. The measurement of the chest must of necessity give some idea of the development of the lungs. These are the organs that furnish the means for the inter-communication between the blood and the oxygen which is so essential not only for all growth but for all functioning as well. The lungs are responsible for

oxygenating the tissues of the body and in this way aid in cellular metabolism. If the lungs are relatively small then the body is without that factor of safety, metabolism is probably slowed down and the amount of exertion under stress is limited. A large supply of oxygen stimulates interchange. The want of it reduces activity. For the growing person the rate of approach to maturity, the physiological age, is retarded. Two methods of measuring have been used by students of the mental and physical growth of school children, the chest circumference and spirometry or the measurement of vital capacity. Porter studied the girth of the chest of the school children of St. Louis and found that the bright children have a larger chest circumference than the dull. The results of Gratsianoff and Sach agree with Porter in this respect. Kline found the chest girth of truants to be less than that of public school children at all ages except at ten. Wiazemsky found good children, that is the bright, to be superior to the poor at all ages except twelve to thirteen and fourteen to fifteen. He also found that robust children were superior at all ages. Also those of good conduct were superior to those of bad at all ages except thirteen to fourteen and sixteen to seventeen. Not only did Wiazemsky point out the above but also the significant fact that the occupation reflects itself in the development of the chest. From the above it is safe to conclude that there is a correlation between school progress and chest circumference.

While there must, it seems, be a high correlation between chest capacity as shown by chest circumference and vital capacity the two are not synonymous. Other investigators have used spirometry. Spirometry only measures directly the respiratory capacity and indirectly the pulmonary capacity. Gilbert found that there was no constant relationship between mental ability and vital capacity until ten to fifteen when the duller children had the larger capacity. Smedley in his investigation found that the vital capacity was much greater in the children of higher school standing. Goddard has pointed out that the vital capacity of feeble-minded children is smaller than that of the normal. Montessori states that among children that are recognized as the brightest she has been able to recognize two categories, those who are exceptionally intelligent and those who are exceptionally studious. The former have better chest development than the latter.

In general vital capacity in its growth follows the same laws as weight, showing the same periods of retardation and acceleration. Practically all investigators have found that boys have larger vital capacities at all ages than girls. Bald-

win's study shows girls with greater vital capacity between thirteen and fourteen. The present study would add also the ages of seven and nine. On the basis of mental age the accelerated boys have better vital capacity than normal at all ages except eight and fourteen. The retarded are inferior to the normal except at eight, when they are equal, and at twelve. At no age do the retarded show a vital capacity equal to the accelerated except at eight. Accelerated girls are superior to normal at all ages except seven and twelve. The retarded are superior to the normal at thirteen and fourteen. At thirteen the retarded are superior to the normal but at no other age.

Thus accelerated boys have greater vital capacity than retarded at all ages except that of eight, when they are equal, and the same general rule is true of girls except for the age of thirteen. Again the same tendency toward a uniformity of growth is noticed for the accelerated and the normal. Also the same period of retardation in the earlier school years, followed by rapid growth, which is more marked with the retarded girls than with the boys. (See Table III.)

Growth, which is an exceedingly complex process, manifests itself in three laws studied by many investigators but especially discussed by Wiazemsky. First is the law of periodicity. According to this law, the growth of the organism is subject to accelerations and retardations. While this law is seen to an extent in all the groups studied it is much more noticeable in the retarded. It would seem that during the earlier school years some factor, or perhaps several is at work which tends to slow down the growth process. Baldwin, studying the taller and heavier children as a group found that the period of acceleration and arrest began and ended earlier with them than among those below the median height and weight. Then when development is arrested at any of its regular growth periods by unfavorable circumstances, there is a tendency for a later rapid growth to compensate for lost time. The brevity of the period of retardation is compensated for by the extent of growth and vice versa the slowness of the growth rate by the length of time. In the third place there is the law of correlation. The human body is wonderfully complex. If it is to grow and function properly there must be a proper correlation of its parts. The digestive system must be equal to the task of furnishing an adequate amount of nutritive material. The lungs must be large enough to supply not only the average need but also a factor of safety for the moments of intense effort. The heart and the arteries are responsible for conveying a sufficient amount of material to the growing

and functioning parts. Unless such a correlation exists growth can not be equal and uniform. Some parts must grow at the expense of others. Protective measures for the preserving of energy must arise. On this point in the absence of further investigation we can not speak. As the matter now stands, the brighter children are those who seem to have this balance or even an excess on the side of vital capacity. The other systems mentioned have not been studied in this connection.

On the basis of mental age, accelerated boys are as a rule taller and heavier and have larger vital capacities than the retarded, while with the girls studied the retarded excel in height and weight during the rapid growth period and also in vital capacity at the age of thirteen. This of necessity means that there are many groups of accelerated that are below the average of their age in the measurements mentioned. This was recognized by Porter and the investigators following him. It was pointed out by these that the small accelerated were taller and heavier than the small retarded.

If height and weight are to be considered as expressions of physiological age as many think, and the writer believes that this is true of the average, then it would seem that children must be differentiated into types. Then as a rule the taller and heavier for the type would be physiologically the more mature. But it is yet a question whether or not this would solve the problem. For one would have yet in classifying a child to determine whether it was a case of type or physiological retardation, in which case the height and weight would be the result of some unfavorable factor acting upon the growth process. Is there not some underlying principle which will harmonize the conflicting data? Not only the energy of growth but the energy of work hangs on the metabolic balance. With the production of work there must be consumption of fuel either of food or of body material. In work of course this consumption is greatly in excess over rest. Probably in no organ is the demand for quick change so great as in the brain. There is growing evidence that the oxygen consumption of the brain is greater than previously thought and it has already been shown that there is a direct relation between the rate of recovery from fatigue and the rate of transmission of the nerve current. In view of these facts it seems reasonable that Whipple's statement of the vital index is correct, that the vital index, the ratio of vital capacity to weight "expresses the balance between body size and the rate and completeness with which oxidation of the blood is or may be affected."

The vital index should it seems give a rough measure of the endurance of the subject and of his recuperative powers. The subject with the higher vital index would then do the greater amount of work. It was shown by illustration in the preliminary work that those children of a given age who were the farther advanced had the higher vital indices.

Kotelman in 1878 was the first to study lung capacity in relation to weight and pointed out the fact that lung capacity increased slightly faster than weight. This conclusion was confirmed by Vierordt. Bobbett in 1909 studied the vital index of Philippine children. Since then Pyle (22) has figured the vital index for Smedley's data showing that the vital index for boys is almost constant at 25 cc. per pound of weight and for girls 23 cc. until eleven. There is then a gradual decrease until fourteen. At this age the index is 21 cc. Baldwin also gives the vital index in his studies of growth.

Our method of classification permits the study of the vital indices of the different groups. At the ages of seven and nine the vital indices of boys and girls are practically the same. At all other ages boys have the higher vital indices. Compared with Smedley's data the vital index of the boy throughout is about the same. The girls do not show the progressive drop after the age of eleven. At the age of eight in our table the average vital index of the accelerated boy is slightly lower than that of the normal. But at no age is the vital index of the retarded as high as that of the accelerated. Consequently there is a marked difference between the vital indices of the accelerated and the retarded boys. With the accelerated girls the vital index is higher at all ages than that of the retarded. However at ten the retarded slightly surpass the normal. But as with boys there is a marked difference between accelerated girls and the retarded. Regardless of age the accelerated show a relatively high vital index while the retarded are relatively low. (See Table IV.)

There is undoubtedly a high correlation between the results of the Binet scale and the teacher's estimate, also between the teacher's estimate and the grade position. So classification on these bases should show the same differences in vital indices although not so great. For the purpose of determining, the vital indices were figured for the work of Gilbert at Yale and the study of Smedley. With Gilbert's study the bright, on the basis of the teachers' estimate, show the higher vital indices at all ages except those of eleven and twelve. The Iowa study does not give as high a correlation. Of the total number of ages studied by Gilbert at Iowa the dull show the lower vital indices in eight and the higher in the remaining

four. Smedley classified the Chicago children into two groups on the basis of the grade age position as follows, those at and above grade and those below grade. The at and above grade group shows the higher vital index at every age except eight and ten. It is to be expected that the difference will be greater in the upper grade, where there is a greater accumulation of retarded on this method of classification. The below grade girls have the higher indices at ten and eleven and are equal to the at and above grade group at thirteen. When compared with the at and above grade boys, the boys from the John Worthy school for truants show lower vital indices except at the ages of nine and twelve. (See Table IV.)

From the above comparisons, in spite of differences of classification, technique, etc., one fact stands out and that is that accelerated children, regardless of the method of classification, show at almost every age the higher vital indices. We believe that the vital index is much more closely correlated with acceleration and retardation than height, weight or vital capacity, and that it is a measure which will harmonize the otherwise conflicting data.

Is there any relation between a high or a low vital index and the development of the child? If it is shown that a relation exists, then the problem becomes an important one for education and hygiene. The vital index can be increased by training which decreases surplus weight and increases the vital capacity. This increase means a better aeration of the blood and, it would seem, an increase in metabolism which would show in endurance and resistance to fatigue or, in other words, in a greater output of work.

It will be objected that spirometry is not altogether a measure of vital capacity. This objection is not without foundation but we believe that the evidence at present shows or at least indicates strongly that the retarded children have smaller chests and presumably smaller lungs due, we believe, to a physiological retardation. It was shown by Porter that those children who were below grade had the smaller chests.

While the measurements of height, weight and vital capacity are of undoubted value they do not give a complete picture of child development. Growth is more than an addition of mass or stature. At birth the child is quite different from the adult in its body proportions. Its growth is an ontogenetic development passing from the form and proportion of the infant to that of puberty and then on to that of the adult. This ontogenetic development can best be traced by the indices of growth, that is, by the relation of weight to height, the height-weight index, by the ratio of sitting to

standing height and by the ratio of chest circumference to height. Not having in mind at the time of collecting the above data the question raised above, the measurements for tracing all these changes were not made, nor is there any single study which enables one to trace all these changes in the same group. However, data of those investigations in which the vital index differences have been shown give some idea of the relationships which we are seeking to establish.

The height-weight index " expresses the comparative solidity or robustness of the individual and other things being equal his general nutrition. There have been two methods of obtaining the height-weight index. The division of the weight by the height gives the proportion of mass for a given unit of height. The most important conclusion on the basis of this method is that the weight increases somewhat faster than the height. This method is held to be faulty by many because it is a comparison of a linear measure with a volume and the resulting indices do not show the transformations of the body as it approaches maturity. It is a matter of common observation that young children have a relatively large proportion of weight for their height, that is, are, as we say, plump. They become thinner before puberty and heavier afterwards. The above method does not bring out this fact. The method used in this connection is expressed by the following formula. The height-weight index equals one hundred times the cube root of the weight divided by the stature. There is a gradual decrease in the indices until just before puberty. From this time until about the age of seventeen the index remains rather constant and then begins to rise as the individual takes on weight, following the pubertal transition. An important study cited by Montessori brings out the fact that the height-weight index of the studious is lower than that for the non-studious. Also that the index is higher for the feeble-minded than for the normal. Consequently she thinks that the sole cause of the physical inferiority of studious children is cerebral fatigue.

Calculating for our own groups and also for Smedley and for Gilbert, the height-weight indices bring out the fact that there is a tendency for the retarded to show the higher indices. (See Table V.)

The second important index is that of the relation of sitting to standing height. This ratio may very well represent the physiological efficiency of the individual. In fact, Collignon spoke of it as the essential stature. This index also enables us to trace the rate of development of the growing child. In early childhood there is an exaggerated trunk length. The

vegetative life is then the most important. With growth this excess gradually decreases until it is least at puberty, following which there is a gradual increase in the excess of trunk length, a return as it were to the more childlike proportion. Thus growth in height until puberty is mainly due to growth of the long bones of the legs. As Godin pointed out, at puberty the lower limbs have a greater dimension in proportion to total height than at any other time. After puberty the proportion of the trunk for boys increases until about seventeen, after which the individual may grow in height but the proportion remains rather constant. With girls the proportion of the trunk continues to increase after this age.

The deviation from the norm of a given age represents in the growing child either a retarded or an accelerated development; and in connection with the other indices gives us a measure of the rate of approach to maturity.

A study of the Smedley groups not only bears out this generalization but shows a close relation between the rate of development and the vital index. Those with the higher, show the more rapid transformation, while the below grade are the retarded and show the lower vital indices. These differences are seen when we compare the retarded and the accelerated girls also with the two groups of the boys and again when we compared the at and above grade boys and the boys from the John Worthy School. (See Table VI.)

We do not have the data to show the relation existing between the ratio of chest circumference on the one hand and the vital index on the other. However retarded children have a smaller chest circumference than accelerated as was shown by Porter. There is a need of study of all of these relationships in the same group of children.

While no thoroughgoing conclusion can be drawn, yet as a general rule accelerated boys are taller, weigh more and have the greater vital capacity. Accelerated girls have the greater vital capacity but the retarded are taller and heavier during the greater part of the rapid growth period. With both the boys and girls the vital index of the accelerated is greater at all ages than that of the retarded. With weight the reverse is true. The retarded show a greater proportion of weight per unit of height than do the accelerated. There are, however, exceptions to this rule, but the general tendency seems to be for the accelerated to show the lower proportion of mass with the higher vital index, as it were a relatively low mass highly oxygenated. The opposite holds for the retarded. The study of the ratio of sitting to standing height brings out the fact that those children with the higher vital

indices are approaching maturity in advance of the low vital index groups, that is, are relatively more mature for the same chronological age.

Those children of a given chronological age who have the higher vital indices are then the more mature and test mentally higher than those with the lower vital indices. Consequently then compulsory school entrance at the age of six must mean that a large number of the entering children are not six physiologically or mentally and so are doomed to failure if the school maintains a fairly uniform standard of work. Many of them after marking time until they are sufficiently mature pass through the remaining grades without difficulty. Again the question is raised whether the two groups described as accelerated and retarded are not after all types in need of radically different treatment. With a classification on the basis of the mental age the physiological differences do not disappear. Although there is little evidence on which to base the opinion, the writer has been unable to escape the conviction that the low vital index group furnishes the majority of those who fail in the lower grades and also of those who are eliminated in the upper grades. This, however, is being made the subject of a separate investigation.

In conclusion the writer wishes to express his appreciation to the members of the staff of the Colorado Teacher's College Training School who made possible the collection of the data of this paper and to express his sincere thanks to President Hall and Dr. Burnham of Clark University, who, for criticism and suggestion, gave so generously of their time.

TABLE I

HEIGHT IN INCHES

Age.....	7	8	9	10	11	12	13	14	15
Boys.....	47.9	51.0	52.0	54.0	56.0	56.4	60.1	60.0	64.3
Girls.....	48.9	50.0	52.8	53.6	55.3	57.5	61.2	61.0	62.8
Boys									
Ac*.....	49.0	50.3	52.0	54.5	56.5	56.3	60.0	60.5	....
Norm.....	46.0	49.8	50.7	53.5	56.1	57.5	60.0	63.4	67.0
Ret.....	....	52.0	....	51.5	52.0	55.5	60.5	58.0	64.0
Girls									
Ac.....	49.0	51.0	51.8	52.5	56.0	56.0	60.3	63.0	....
Norm.....	49.0	50.5	53.5	55.0	54.7	57.8	59.2	59.3	62.0
Ret.....	....	50.3	....	52.5	57.0	57.5	62.8	61.7	64.3

*Ac., Accelerated: Those testing one year and above chronological age. Norm., Normal: Those testing at age. Ret., Retarded: Those testing one year and not more than three below the chronological age.

TABLE II

Weight in Pounds

Age.....	7	8	9	10	11	12	13	14	15
Boys.....	49.8	61.3	60.4	67.8	75.5	81.1	90.6	87.0	116.5
Girls.....	54.7	57.3	63.7	64.3	72.3	79.7	100.1	107.1	113.0
Boys									
Ac.....	51.0	61.0	59.4	69.6	72.6	82.2	91.3	84.5	....
Norm.....	46.5	61.0	61.7	71.5	78.3	77.0	89.0	93.0	137.0
Ret.....	....	65.0	....	59.0	64.0	82.0	94.5	82.3	114.0
Girls									
Ac.....	44.0	58.0	62.5	60.0	70.0	70.0	96.6	101.0	....
Norm.....	60.5	61.5	65.4	68.0	72.0	83.2	85.4	100.0	116.0
Ret.....	....	53.0	....	61.0	76.0	77.8	121.2	112.8	112.0

TABLE III

Vital Capacity in Liters

Age.....	7	8	9	10	11	12	13	14	15
Boys.....	1.24	1.53	1.50	1.76	2.01	2.18	2.34	2.15	2.98
Girls.....	1.23	1.30	1.59	1.64	1.77	1.90	2.36	2.35	2.63
Boys									
Ac.....	1.30	1.50	1.60	1.94	2.07	2.60	2.60	2.30	....
Norm.....	1.15	1.55	1.37	1.75	2.02	1.95	2.25	2.36	3.60
Ret.....	....	1.50	....	1.35	1.50	1.75	2.25	2.10	2.91
Girls									
Ac.....	1.20	1.53	1.63	1.80	1.90	1.90	2.47	2.80	....
Norm.....	1.30	1.45	1.57	1.63	1.66	2.40	2.06	2.25	3.00
Ret.....	....	1.00	....	1.50	1.60	1.72	2.65	2.38	2.50

TABLE IV

Vital Index

Age.....	7	8	9	10	11	12	13	14	15
Boys.....	24.9	24.9	24.8	25.9	26.6	26.9	25.8	24.7	25.6
Girls.....	22.5	22.8	24.9	25.5	24.5	23.8	23.6	21.9	23.3
Boys									
Ac.....	25.5	24.6	26.7	27.9	28.5	30.4	28.5	27.2	....
Norm.....	24.7	25.4	22.2	24.6	25.7	25.3	25.3	25.4	26.2
Ret.....	....	23.1	....	22.9	23.4	21.3	23.9	23.5	25.5
Girls									
Ac.....	27.3	26.0	26.2	30.0	27.1	27.1	25.6	27.7	....
Norm.....	21.5	23.6	24.2	23.9	23.1	24.5	24.2	22.5	25.9
Ret.....	....	18.9	....	24.6	21.1	22.1	21.9	21.1	22.3
Smedley Boys									
At and above grade	25.1	25.8	25.0	25.3	25.4	25.5	25.0	26.3	
Below grade.....	26.3	24.9	25.5	25.0	24.3	25.2	25.0	24.7	
John Worthy School	...	26.1	25.0	24.4	25.7	24.8	25.1	24.5	

TABLE IV—*Continued*

Girls								
At and above grade	23.0	23.3	22.6	22.4	21.8	20.6	20.6	20.6
Below grade.....	22.7	22.9	23.4	22.5	21.1	20.6	20.3	19.1
Gilbert—Yale Study								
Bright..... 22.1	21.9	21.8	21.4	21.7	20.8	22.6	19.4	21.8
Dull..... 20.8	20.1	21.1	19.3	21.9	21.7	18.9	17.3	19.9

TABLE V

HEIGHT-WEIGHT INDEX

Boys								
Age..... 7	8	9	10	11	12	13	14	15
Ac..... 22.9	23.9	22.7	22.6	22.3	23.5	22.7	21.8	....
Ret.....	23.3	....	22.7	23.3	23.5	22.6	22.7	23.0
Girls								
Ac..... 21.9	22.8	23.0	22.4	22.1	22.1	23.2	22.4	....
Ret.....	22.7	....	22.7	22.3	22.9	23.8	23.6	22.7
Smedley Boys								
At and above grade	23.8	23.1	23.2	23.2	23.1	23.0	23.0	22.9
Below grade.....	23.5	23.5	23.5	23.3	23.3	23.1	22.9	23.2
John Worthy School	....	23.5	23.9	23.6	23.6	23.5	23.4	23.4
Girls								
At and above grade	23.4	23.1	23.1	22.8	22.8	22.9	23.1	23.3
Below grade.....	23.5	23.2	23.4	22.9	22.9	23.0	23.1	23.1
Gilbert								
Bright.....	23.4	23.0	23.2	22.4	22.8	22.7	22.8	22.1
Dull.....	23.6	23.3	22.9	21.6	22.8	22.8	22.4	22.8

TABLE VI

RATIO OF SITTING TO TOTAL STATURE

Smedley Boys								
Age.....	8	9	10	11	12	13	14	15
At and above grade	54.8	54.0	53.5	53.1	52.5	52.1	52.1	52.0
Below grade.....	55.1	54.7	53.8	53.3	52.9	52.2	52.2	51.8
John Worthy School	....	53.7	54.5	53.6	53.4	52.6	52.9	51.0
Girls								
At and above grade	53.9	54.0	53.5	53.1	52.7	52.6	52.9	53.4
Below grade.....	55.4	54.3	53.8	53.4	53.1	52.8	52.1	53.1

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